S&C FY02 ANNUAL REVIEW MEETING

LUT – Online Wall Measurement of Steel Tubes Using Laser-Ultrasonic Technology

Award #DE-FC07-99ID13651

Dr. Robert V. Kolarik II – The Timken Company
Dr. Marc Choquet – Tecnar Automation Ltee

Project Description

- **Design an on-line, non-contact sensor for measuring the wall thickness & eccentricity of hot steel tubing based on laser-ultrasonic technology**
- **Build a cost effective, modular system which could be easily upgraded or relocated**
- **Transition the technology to an industrial environment demonstrating the long-term utility of the technology**

Project Objectives/Goal

- **IOF need(s) addressed by this technology**
  - Reduction of energy usage & gas emissions to produce tubing through increased efficiency & minimized scrap & rework
- **Objectives**
  - Provide real-time, accurate wall thickness measurements
  - Present full-length wall variation & eccentricity plots
  - Deliver a robust system with excellent reliability & performance
- **Overall goal**
  - Provide a sensor for application throughout the metals industries to reduce energy intensity of tubing manufacture

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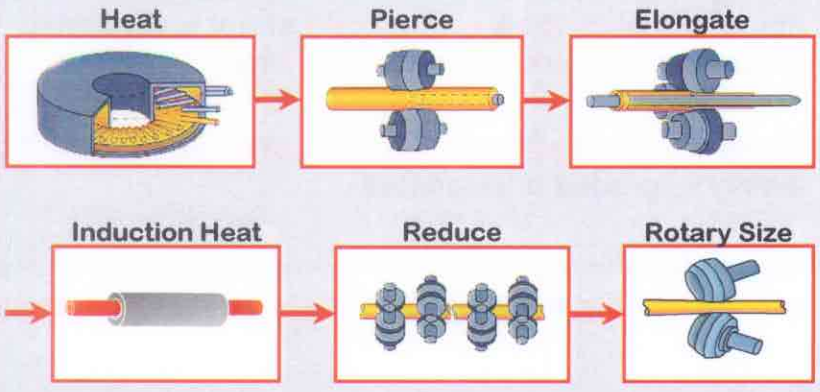
Process Description



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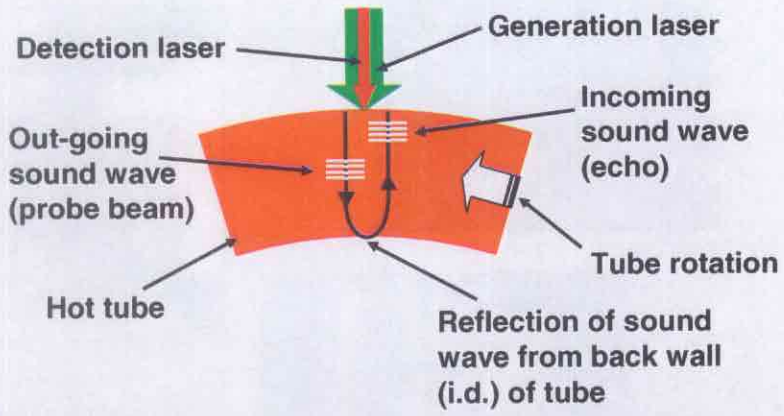
Principle of Laser-Ultrasonics



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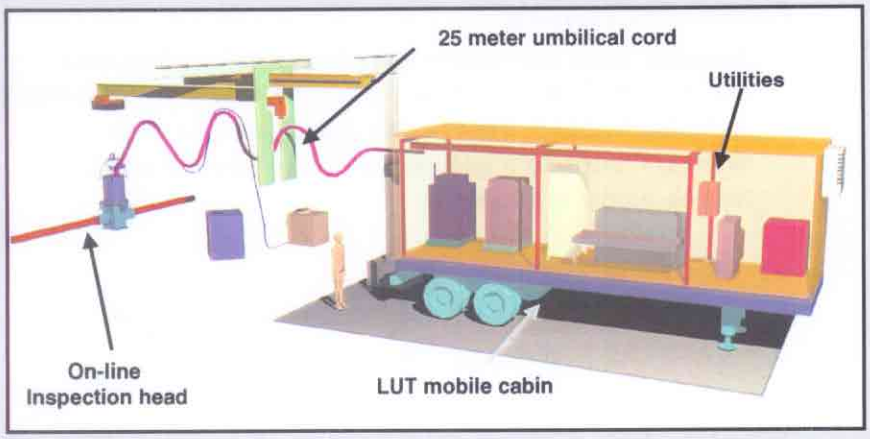
Description of LUT System



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Deployed LUT System

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Productivity Savings

- **Faster size checks**
  - Formerly, done with manual sampling - requiring 5 minutes: cut, quench, dress, measure, calculate & record, adjust & repeat
  - Sampling limited to a few pieces, only at extreme ends
  - With LUT, immediate wall display - every tube, full length - no loss of time or material
- **Better mill set-ups**
  - Reduced out of tolerance product - less scrap & rework
  - Reduced troubleshooting time

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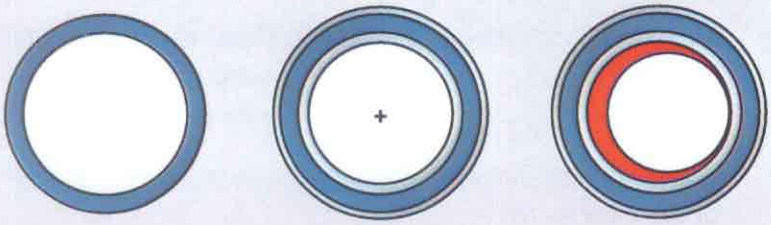
Material Savings



Desired Tube

Desired Tube with Minimum OD & ID Clean-up Stock

Desired Tube with Added ID Clean-up Stock for Eccentricity

Technical Risks/Innovation

- **Technical risks**
  - Ability to capture echo at known temperature & position
- **Innovation**
  - Fiber optic coupling of lasers to tube
  - Real-time, non-contact measurement of temperature
  - Laser velocimetry for position determination
- **Advancement of state-of-the-art; over competition**
  - Radiation source gauges
    - source can't be switched off
    - limited on small o.d. tubing
    - can't be used if a mandrel bar is present inside

Technical Hurdles

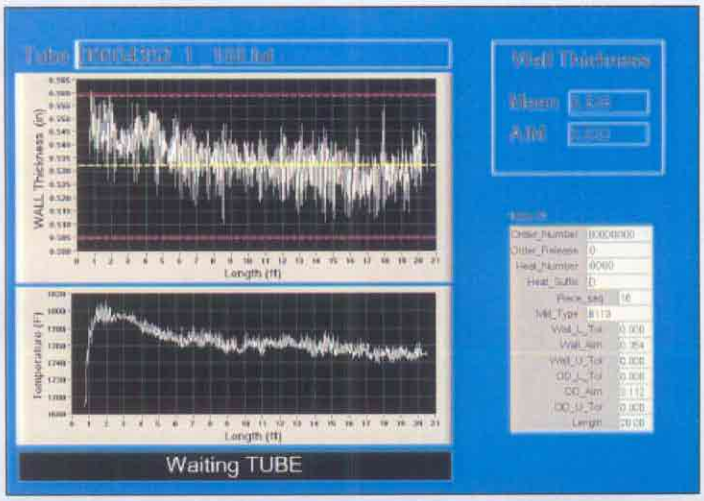
- **Development tasks**
  - Assemble a robust system for steel mill operation on a routine basis
  - Design & build non-contact location measuring device
  - Adapt a non-contact temperature measuring device for operation in the presence of high power IR lasers
  - Design & build a control software for operation of the sensor by plant personnel
  - Design & build data processing software
  - Design & build data display software with network transfer of data

Task Performance

Past Technical Milestones

Milestone	Due Date	Completion Date	Comments
R&D Exploratory Report	*11/24/1999*	*3/29/2000*	*Extended for grain size investigation*
System Design Report	*3/30/2000*	*3/29/2000*	
System Integration & Testing Report	*10/03/2000*	*6/30/2001*	*Delayed by late laser delivery*
In-plant Testing Report	*4/27/2001*	*10/22/2001*	*Limited scope to recover schedule*

LUT – On-line Data Display



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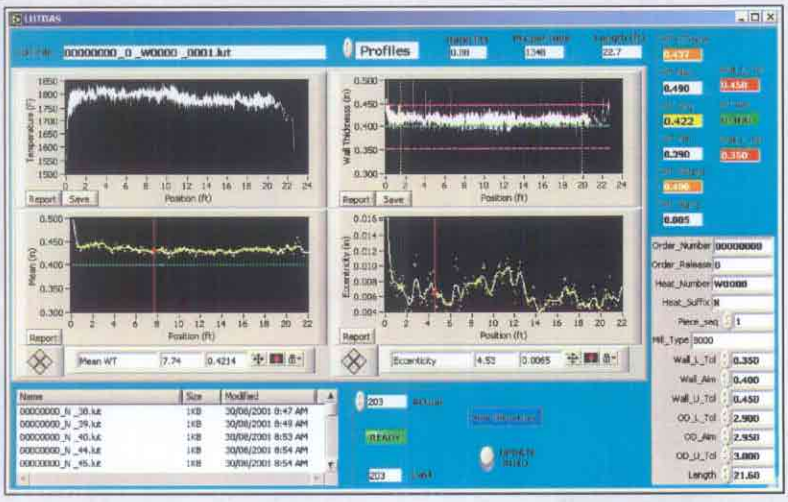
LUT – Data Viewing Software



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LUT – Printable Report

LUT GAUGE REPORT

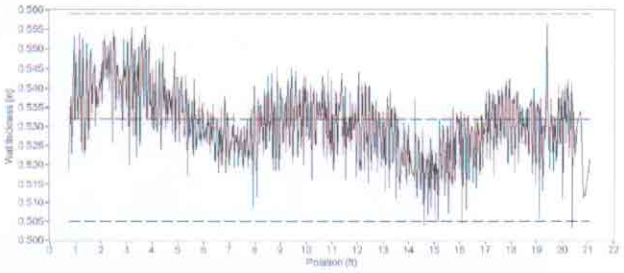
Client: XXXX
Order number: 0123
Tube number: 0123

Steel type: XXXX
Tube length: 23
Tube OD: 5

Process ID: ZZ
Note: XXXXX

Lower Wall Tolerance : 0.505 | Aimed Wall: 0.532 | Upper Wall Tolerance 0.559

Minimum value: 0.503 | Average value: 0.531 | Maximum value: 0.556



Thursday, October 04, 2001

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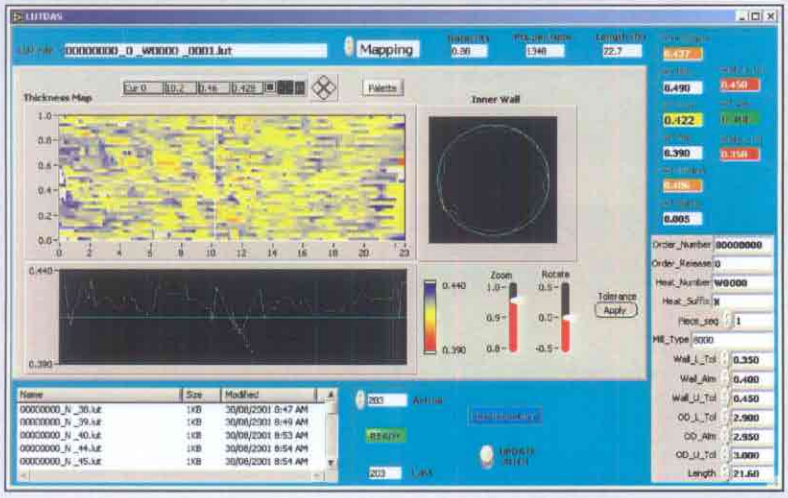
LUT – Data Viewing Software



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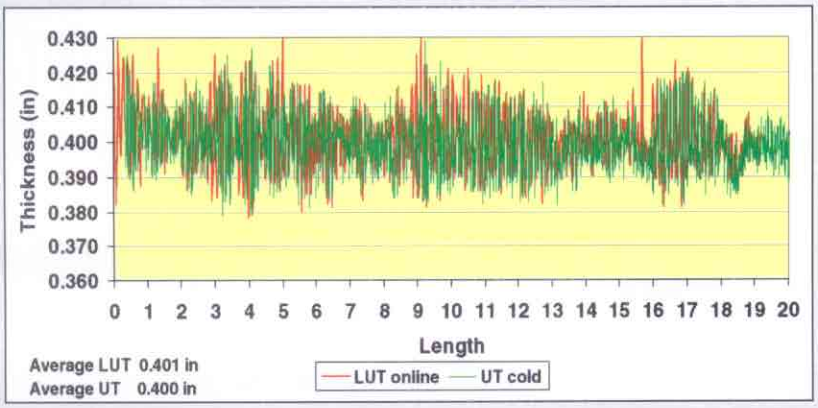
LUT - Wall Pattern Results

- **Wall variation pattern verification**



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LUT - Accuracy Results

- **Accuracy verification +/- 0.5% @ room temperature**
  - Initial study - five tubes, one grade

	Average Wall Thickness - inches			
Tube	LUT	Final	Difference	%
1	0.401	0.400	0.001	0.25
2	0.395	0.392	0.003	0.77
3	0.396	0.395	0.001	0.25
4	0.396	0.395	0.001	0.25
5	0.396	0.393	0.003	0.76
	Average % Difference =			0.46

  - Broad study - nine tubes each on 17 orders varying grade, o.d./wall

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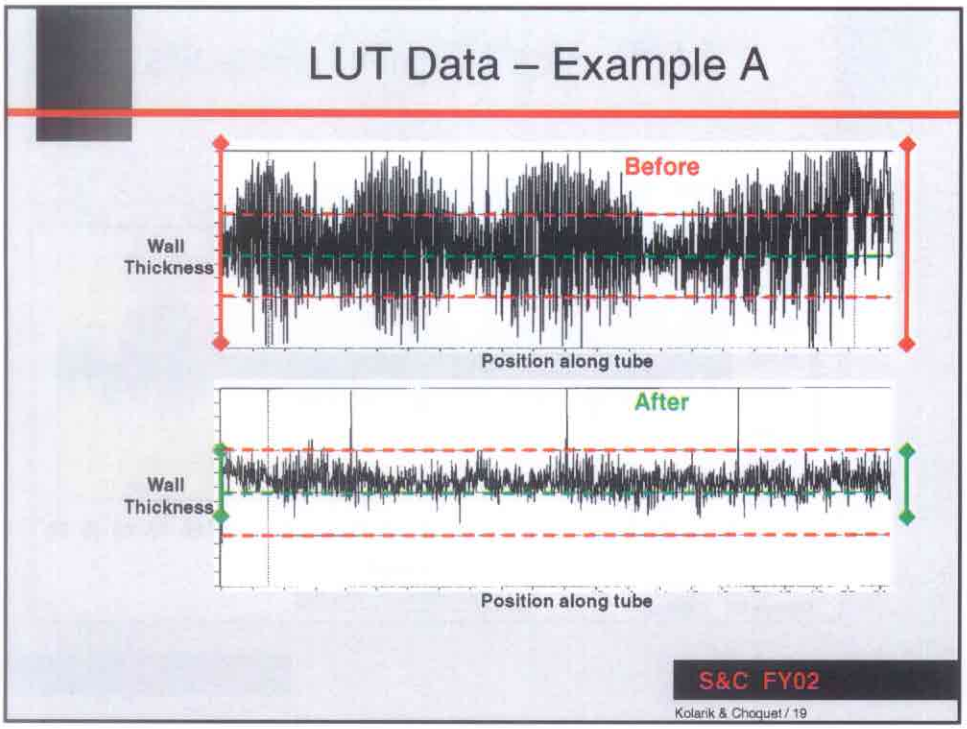
LUT Data – Example A
Before
Wall Thickness
Position along tube
After
Wall Thickness
Position along tube
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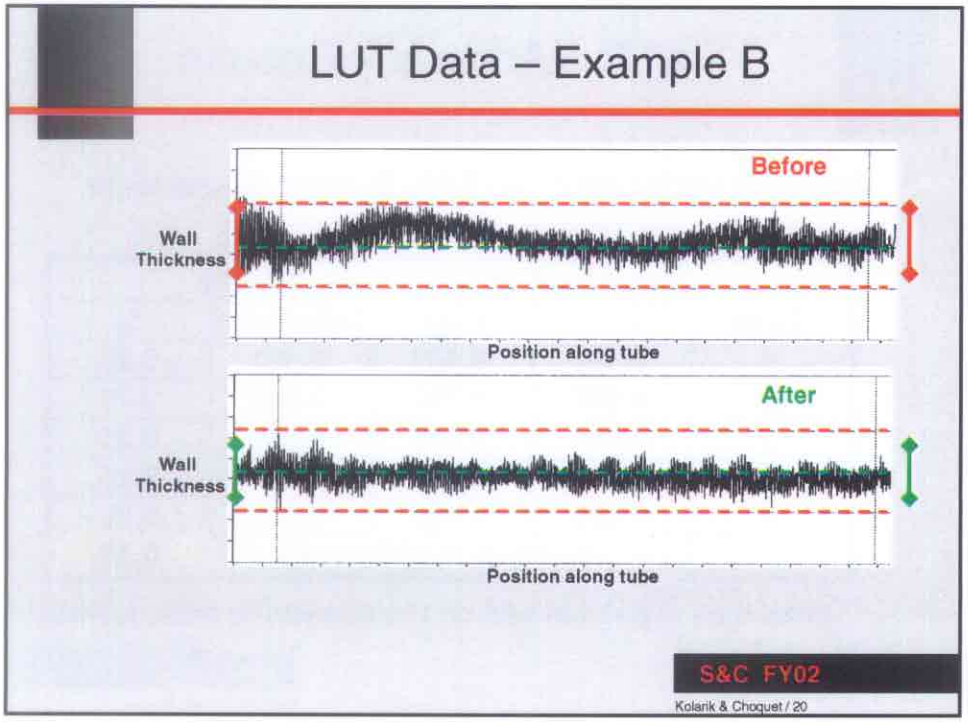
LUT Data – Example B
Before
Wall Thickness
Position along tube
After
Wall Thickness
Position along tube
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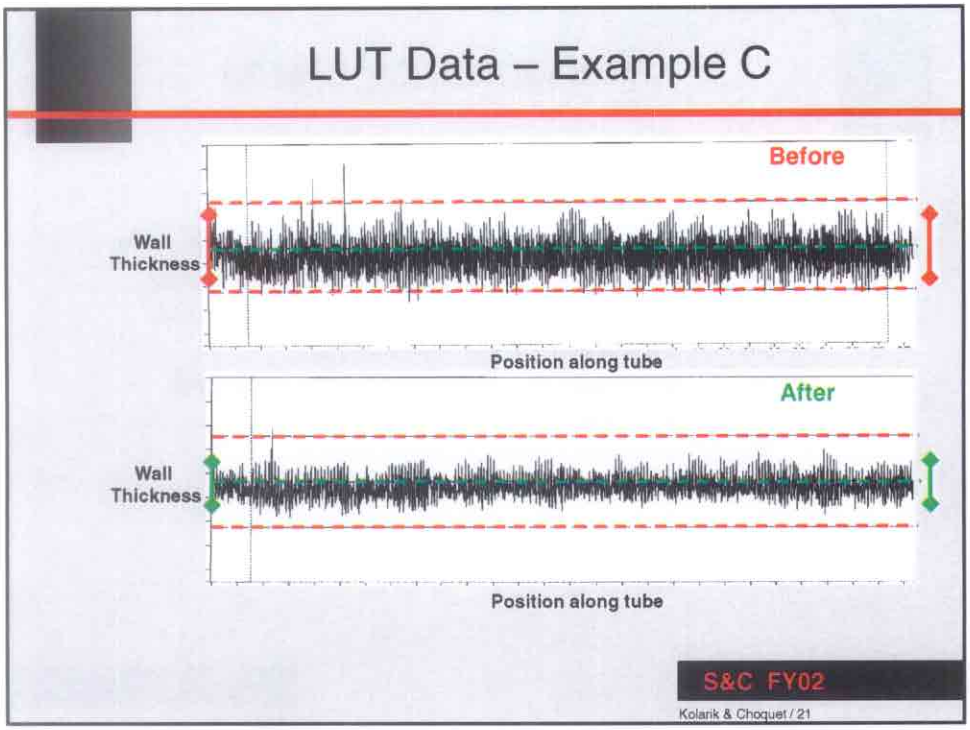
LUT Data – Example C
Before
Wall Thickness
Position along tube
After
Wall Thickness
Position along tube
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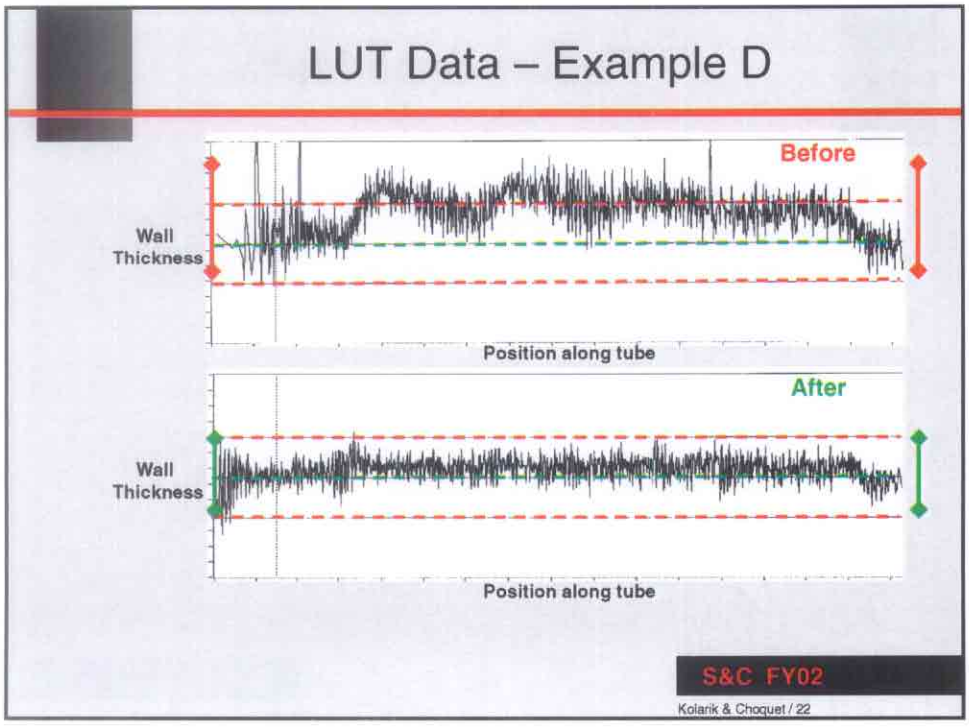
LUT Data – Example D
Before
Wall Thickness
Position along tube
After
Wall Thickness
Position along tube
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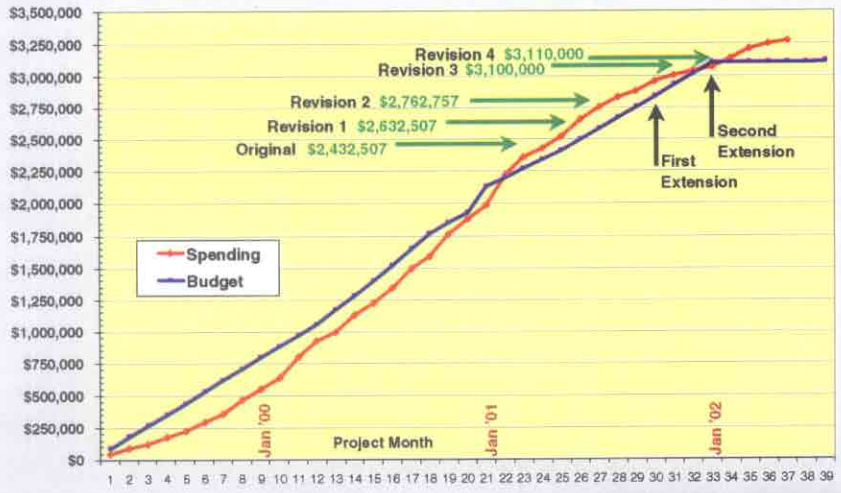
Performance Merits

- **Reliability**
  - More than 100,000 tubes inspected since March deployment
  - Availability - already at 92%, reasonable to approach 98%
    - 73% LUT online - percentage of production measured basis
    - 19% LUT unscheduled - system enhancement
    - 3% LUT scheduled - unavailable due to component repair
    - 2% LUT scheduled - system unable to measure
    - 3% LUT scheduled - communications failures

Performance Merits

- **Cost reduction**
  - Derived from
    - reduced sampling & decision making time
    - reduced loss of material in sampling
    - reduced rework
    - reduced scrap & remanufacture
  - Conservatively estimated at six-figure potential
    - verified, even from improved state since project start
    - actually exceeded by 5% in initial data

Project Budget



Commercialization

- **Commercialization path & partners**
  - Public announcement of availability of system made by Timken
  - Commercialization agreement under final revision, including royalty terms
  - Tentative decision made on commercializer/equipment builder
  - Discussions underway for improvement of technology

Commercialization

- **Price**
  - competitive with radiation gauges
- **Estimated return on investment**
  - 1-2 years, based on expected price & anticipated savings

Path Forward

Future Technical Milestones

Milestone	Due Date	Completion Date	Comments
Feature Extraction Report	*7/31/2002*		*Task halted, findings in final report*
Final Report	*7/31/2002*		*Due date actually 10/31*

Conclusion

- **Project results**
  - Sensor system developed which meets target accuracy
  - All technical objectives achieved
  - Reliability acceptable for industrial use
  - Performance has delighted customer
  - Preliminary assessment shows savings achieved
- **Next phase**
  - Continued use for process improvement for benefit capture
  - Continued improvement for increase robustness & reliability